Preliminary plan for monitoring the impacts of desertification and climate change

Famine Early Warning System Network (FEWS NET)
U.S. Agency for International Development (USAID)
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Introduction

In 1985, in response to another grave episode of drought and famine in semi-arid areas in Africa, USAID initiated the Famine Early Warning System (FEWS). The objective of FEWS was to provide host country and U.S. decision-makers with timely and accurate information on potential drought and famine. In May 2000, the program began its fourth phase as a redesigned activity, the Famine Early Warning System Network (FEWS NET). The objective of FEWS NET is to reinforce African country capacities to monitor drought and plan for potential famine. FEWS NET works in the same 17 drought-prone African countries (Figure 1) in which FEWS has worked since 1994.

The FEWS NET implementing partners are a team of U.S. government agencies with expertise in environmental monitoring: the Foreign Agricultural Service (FAS), National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), USAID, and the U.S. Geological Survey (USGS). The principal African partners are regional early warning organizations: the Centre Régional AGRHYMET, Niamey, Niger, a specialized institution of the Comité Permanent Inter-États de Lutte contre la Sécheresse au Sahel (CILSS); the Drought Monitoring Centre, Nairobi, Kenya; and the Regional Early Warning Unit (REWU) of the Southern African Development Community (SADC), Harare, Zimbabwe. FEWS NET will continue the U.S. Government practice of making all data and information free and accessible to the public.

The main activities that FEWS NET undertakes includes satellite monitoring of vegetation and rainfall, field monitoring of agricultural production and marketing, analysis of vulnerability, consensus planning to respond to food insecurity, food aid targeting, and building capacities of local food security organizations. FEWS NET is also starting a program to monitor the impacts of desertification and climate change. This report first summarizes FEWS NET satellite monitoring methods, then summarizes FEWS net field monitoring activities, and then describes the preliminary plan for monitoring the impacts of desertification and climate change.

Satellite monitoring

USAID provides funding to NASA, NOAA, and USGS for satellite operations and data acquisition and analysis that support FEWS NET. The normalized difference vegetation index (NDVI), developed by NASA scientist Compton J. Tucker (1979) and the rainfall estimate (RFE) algorithm developed by NOAA scientists (Herman *et* *al.* 1997) constitute the principal remote sensing tools that FEWS NET uses to evaluate environmental conditions. In cases where FEWS NET requires higher-resolution data, it also utilizes data from the LANDSAT-7, Terra, and Tropical Rainfall Measuring Mission (TRMM) satellites. Table 1 summarizes the principal and supplementary satellite data sources for FEWS NET.

NDVI is an indicator of vegetative production derived from remotely sensed data in the red and near-infrared spectral regions. Because chlorophyll-a absorbs a maximum amount of light at a wavelength in the red region, 640 nm, photosynthetic efficiency is maximized and reflectance is minimized at this wavelength. The Advanced Very High Resolution Radiometer (AVHRR) sensor of NOAA satellites, a series of heliosynchronous, polar-orbiting satellites with a nadir spatial resolution of 1.1 km, senses light in the red region, wavelengths 550-680 nm, on Channel 1. The Channel 1 spectral response is therefore inversely related to chlorophyll density. AVHRR Channel 2 senses near-infrared light, wavelengths 730 nm-1.1 µm. The Channel 2 spectral response is directly related to scattering in individual leaves and between leaves in the canopy. Combining the two channels accounts for differences in irradiance and indicates the intercepted fraction of photosynthetically active radiation or photosynthetic activity: NDVI = [Channel 1–Channel 2]/[Channel 1+Channel 2]. AVHRR Channel 5, which senses at 11.5-12.5 µm, detects temperatures colder than 12 C and provides a mask with which to correct NDVI for clouds. Integration of NDVI over the growing season yields an index of total production (Tucker *et al.* 1981).

Figures 2 and 3 show the map products that FEWS NET currently makes available at <http://www.info.usaid.gov/fews>. For every ten-day period, NASA and USGS produce NDVI data and maps for Africa and maps comparing current NDVI to 1984-1993 averages.

NOAA and USGS produce the second most important remote sensing product for FEWS NET, a rainfall estimate (RFE) based on Meteosat-5 cold cloud duration, rain gauges, wind speeds, relative humidity, and elevation. For every ten-day period, FEWS NET provides RFE data and maps (Figure 4) for Africa and currently provides maps comparing the current RFE to last year (Figure 5) and to 1920-1980 averages (Figure 6). NOAA is

Table 1. FEWS NET remote sensing data sources

satellite	sensor	product
principal data sources		
NOAA-14	AVHRR	8 km and 1 km NDVI
Meteosat-5	infrared	rainfall estimate
supplemental data sources		
Defense Meteorological Satellite Program (DMSP)	SSM/I	rainfall estimate
LANDSAT-7	Enhanced Thematic Mapper (ETM+)	land cover
Terra	MODIS	250 m NDVI
Tropical Rainfall Measuring Mission (TRMM)	Microwave Imager (TMI)	rainfall estimate

in the process of developing a more accurate RFE algorithm for FEWS NET that will take advantage of the ability of microwave sensors on Defense Meteorological Satellite Program satellites to measure the latent heat released by precipitation.

Field monitoring

FEWS NET stations field representatives in 15 of its 17 countries, with representatives in Kenya covering Somalia and Sudan. The field representatives travel regularly through rural areas to observe the progress of the agricultural season and to gather data on production and marketing. They compile their information in monthly reports for distribution to host country and international organizations. The reports contain information on the vegetative cover, rainfall, agricultural and pastoral production, price trends, terms of trade, pest outbreaks, and any other factors that might signal the early signs of drought or famine.

Annually, the field representatives compile their information into a current vulnerability analysis (CVA) that identifies the geographic areas in which an average household cannot maintain its customary food consumption patterns during the next year without turning to strategies that may compromise its future food production and income generation capacities. For the 1999-2000 season, FEWS estimated that, in Burkina Faso, Chad, Mali, Mauritania, and Niger 49 000, people live in areas of extreme food insecurity, 1.6 million people live in areas of high food insecurity, and 3.8 million people live in areas of moderate food insecurity.

Monitoring Desertification and Climate Change

In tracking short-term environmental conditions, FEWS NET uses the same remote sensing and field methods used to monitor long-term environmental phenomena. In 1999, recognizing the imperative to apply the work of FEWS NET to the global environmental phenomena of desertification and CO_2-induced climate change, USAID initiated an assessment of long-term monitoring methods. Four main activities will form the FEWS NET program:

1. Analysis of NDVI data series
2. Field analysis of forest species distributions
3. Analysis of chronic vulnerability
4. Training of host country partners in monitoring methods

The USGS has now corrected the 1981-1999 8 km NDVI data series for Africa in Albers geographic projection. This data cube (latitude, longitude, time) provides the basis to confidently compare current NDVI readings with a 19-year mean. FEWS NET may analyze the linear trend for each pixel to determine areas of decreasing vegetative productivity. Moreover, FEWS NET may also assist AGRHYMET in cleaning up the 1990-1999 1 km NDVI archive for West Africa, facilitating a high-resolution analysis of vegetation production trends.

Calculating NDVI from 1980-1990 data along the Sahara-Sahel margin, longitude 16°W-39°E, Tucker *et al.* (1991) tracked the inter-annual variation of the 200 mm y^{-1} isohyet, the approximate limit of vegetative growth and beginning of the Sahara Desert. They found that this limit fluctuated significantly until its 1990 position lay 130 km south of its 1980 position.

In the long-term, net primary productivity (NPP) and standing biomass can provide more useful indicators of desertification and climate change than NDVI alone. Careful measurements of biomass and modeling of vegetative growth (Cramer *et al.* 1999) can generate close estimates of NPP.

NDVI also serves as an input in modeling attempts to determine the relative importance of anthropogenic and climatic factors in explaining rainfall variability in the Sahel. Zeng *et al.* (1999) compared actual rainfall data from the period 1950-1998 with the output of a coupled atmosphere-land-vegetation model incorporating SST, soil moisture, and NDVI. Their results indicate that actual rainfall anomalies are only weakly correlated to SST by itself. Only when the model includes variations in vegetative cover and soil moisture does it come close to matching actual rainfall data.

In addition to the remote sensing analyses, FEWS NET plans to conduct field analyses of forest species distributions. Farmers and herders depend on trees and shrubs both for subsistence and for emergency resources in times of severe drought. Furthermore, trees and shrubs serve vital ecosystems functions by maintaining soil fertility, assuring the proper functioning of the hydrologic cycle, and sequestering carbon.

In 1999 and 2000, FEWS tested forest inventory methods that have documented (Gonzalez 1997, 2000) a 25-30 km southward shift of forest species in Senegal in the past half-century of desertification. The forest species inventory consists of a systematic listing of the presence or absence of all forest species in a village's lands. Village elders provide information on past distributions and actual field surveys give current distributions. Table 2 shows the preliminary results.

Table 2. FEWS field work on forest species declines in the Sahel.

country	village	ethnic group	latitude	longitude	forest species richness	
					ca. 1960	1999-2000
Burkina Faso	Nampabuum	Mossi	13°20	0°50' W	46	42
Chad	Abkiese	Daza	13° N	15°50' E	not yet counted	in decline
Chad	Balatram	Arab	12°50' N	14°50' E	not yet counted	in decline
Mali	Fabougou	Bambara	14°15' N	6°15' W	55	55
Mauritania	Atene	Hal Pulaar-en	16°15' N	13°40' W	43	26
Mauritania	Dioude Walo	Hal Pulaar-en	16°15' N	13°40' W	44	22
Niger	Garia Yabasulu	Zarma	14°25' N	3°20' E	not yet counted	in decline

The information from remote sensing and forest inventory analyses will complement data on socio-economic trends in the analysis of the chronic vulnerability of rural people. Together with analyses of trends from past FEWS current vulnerability analyses, this long-term data will facilitate the identification of geographic areas and socio-economic groups that have experienced a long-term erosion of food security because of desertification and climate change. Indeed, Parry *et al.* (1999) estimate that a doubling of CO_2 in this century may lead to tens of millions more at risk of food insecurity in Africa.

Finally, FEWS NET plans to work with its host country partners to build their capacities to conduct these long-term analyses. FEWS NET will share all of its results, facilitate training sessions on monitoring methods, and link organizations in networks to mobilize the expertise of individual organizations for the benefit of all network members. In this way, FEWS NET aims to contribute to the effective implementation of the U.N. Framework Convention on Climate Change and the U.N. Convention to Combat Desertification.

Literature Cited

Cramer, W., D. W. Kicklighter, A. Bondeau, B. Moore, G. Churkina, B. Nemry, A. Ruimy, A. L. Schloss, and the Potsdam NPP Model Intercomparison. 1999. Comparing global models of terrestrial net primary productivity (NPP): overview and key results. *Global Change Biology* 5: 1-15.

Gonzalez, P. 1997. *Dynamics of biodiversity and human carrying capacity in the Senegal Sahel.* Ph.D. Dissertation, University of California, Berkeley, California.

Gonzalez, P. 2000. Energy use, human. in S. Levin (ed.) *Encyclopedia of biodiversity.* Academic Press, San Diego, California

Herman, A., V.B. Kumar, P.A. Arkin, and J.V. Kousky. 1997. Objectively determined 10-day African rainfall estimates created for famine early warning systems. *International Journal of Remote Sensing* 18: 2147-2159.

Parry, M., C. Rosenzweig, A. Iglesias, G. Fischer, and M. Livermore. 1999. Climate change and world food security: a new assessment. *Global Environmental Change* 9: S51-S67.

Tucker, C.J. 1979. Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment* 8: 127-150.

Tucker, C.J., B.N. Holben, J.H. Elgin, Jr., and J.E. McMurtrey III. 1981. Remote sensing of total dry-matter accumulation in Winter wheat. *Remote Sensing of Environment* 11: 171-189.

Tucker, C.J., H.E. Dregne, and W.W. Newcomb. 1991. Expansion and contraction of the Sahara Desert from 1980 to 1990. *Science* 253: 299-301.

Zeng, N., J.D. Neelin, K.-M. Lau, and C.J. Tucker. 1999. Enhancement of interdecadal climate variability in the Sahel by vegetation interaction. *Science* 286: 1537-1540.

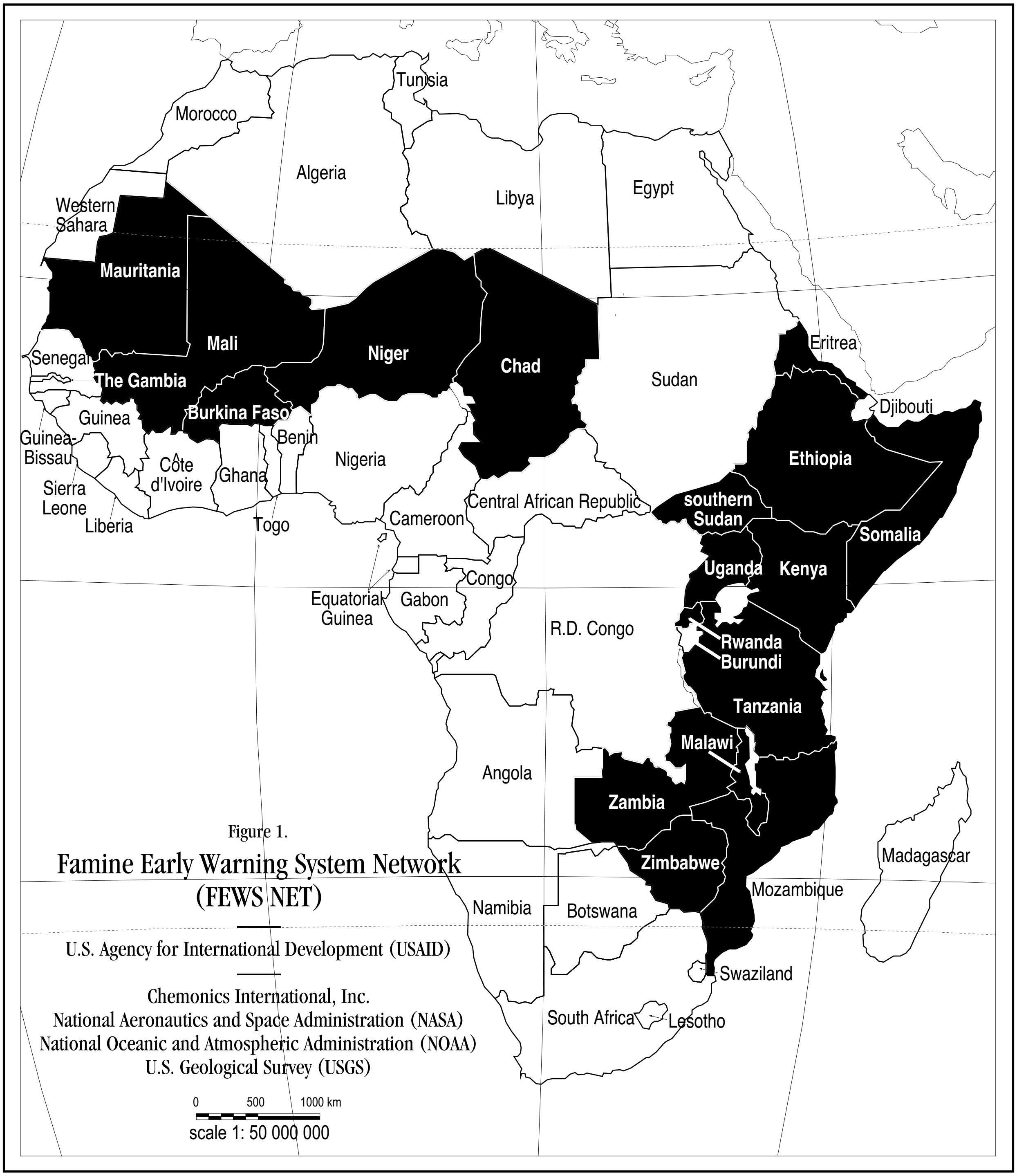

Figure 1.

Famine Early Warning System Network (FEWS NET)

U.S. Agency for International Development (USAID)

Chemonics International, Inc.
National Aeronautics and Space Administration (NASA)
National Oceanic and Atmospheric Administration (NOAA)
U.S. Geological Survey (USGS)

Figure 2. Normalized Difference Vegetation Index (NDVI) May 10-20, 2000

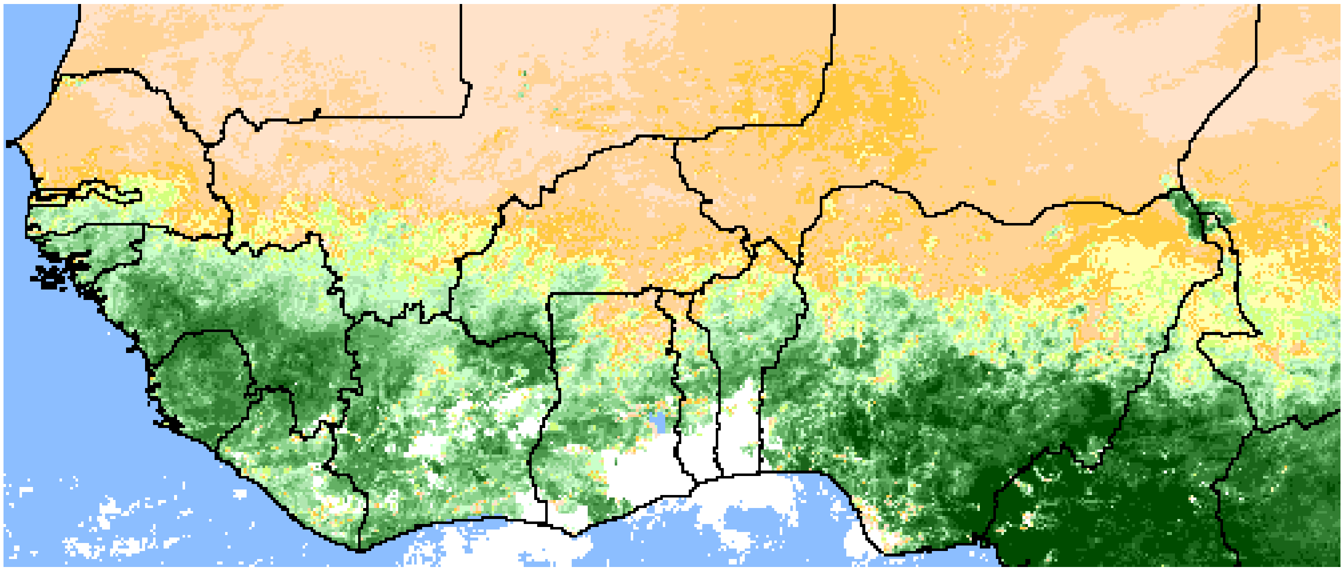

Figure 3. NDVI difference from 1984-1993 mean

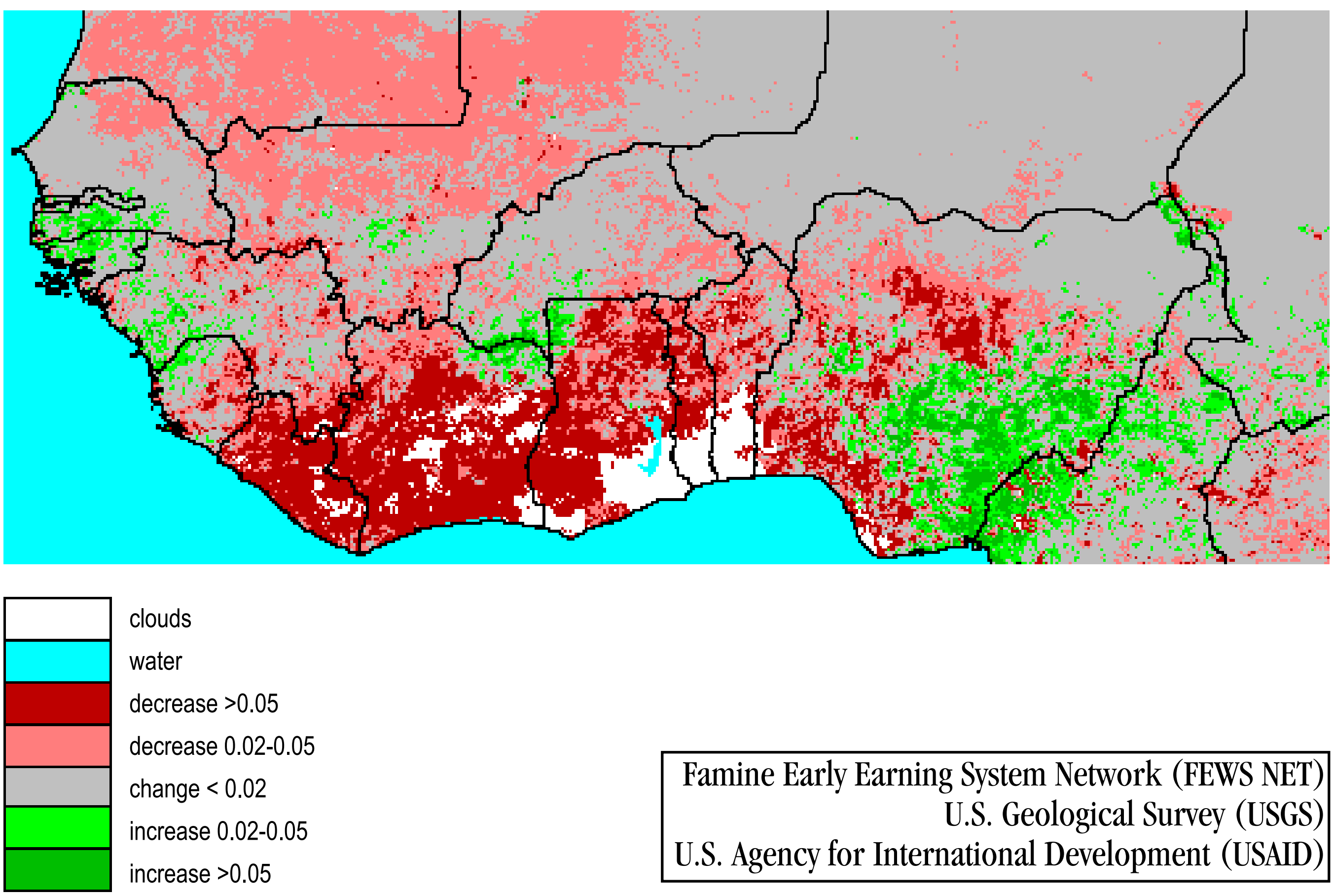

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Figure 4. **Rainfall estimate (mm) May 1-10, 2000**

based on Meteosat-5 cold cloud duration, rain gauges, wind speeds, relative humidity, and elevation

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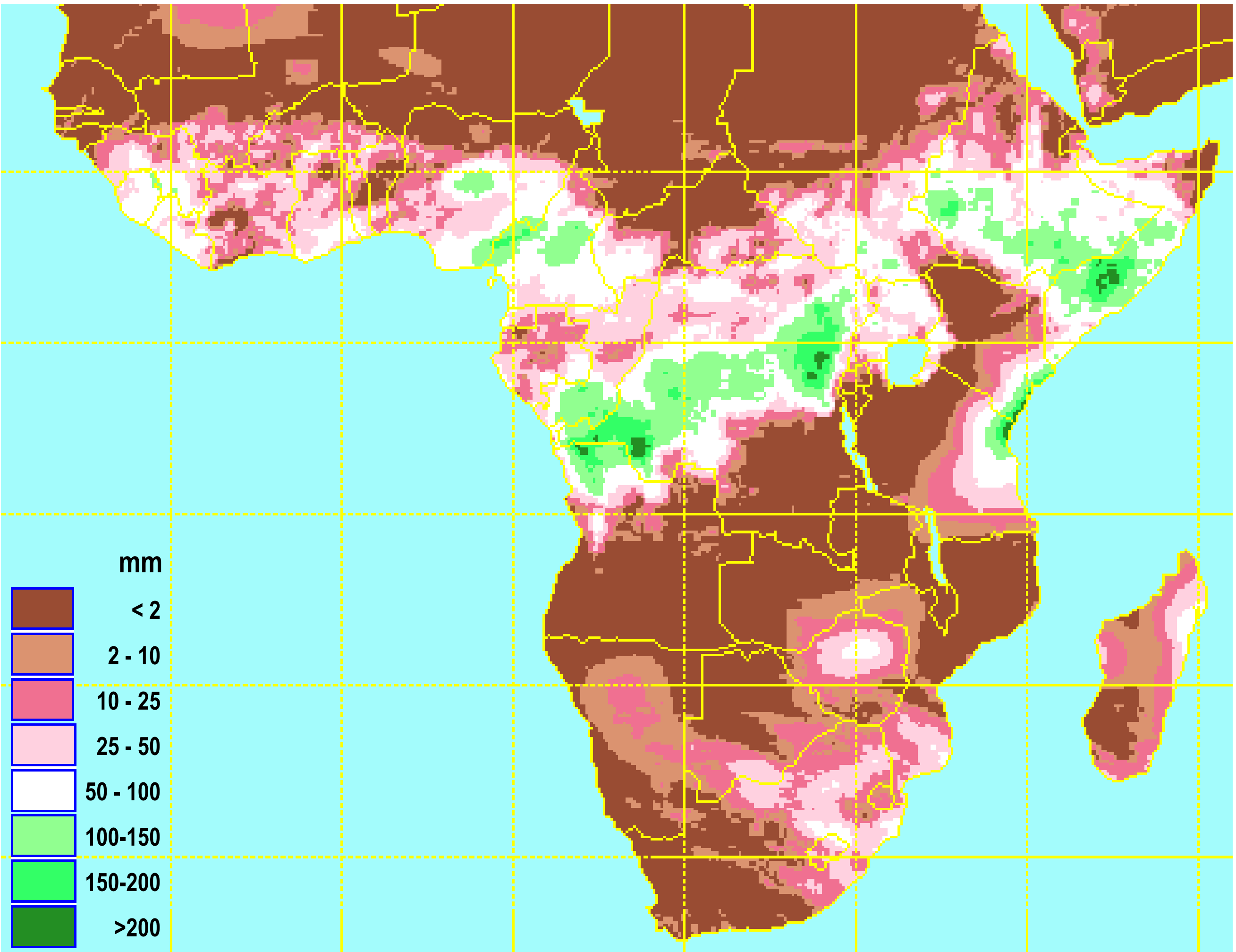

Figure 5. Difference from 1999

- great decrease
- slight decrease
- no change
- slight increase
- great increase

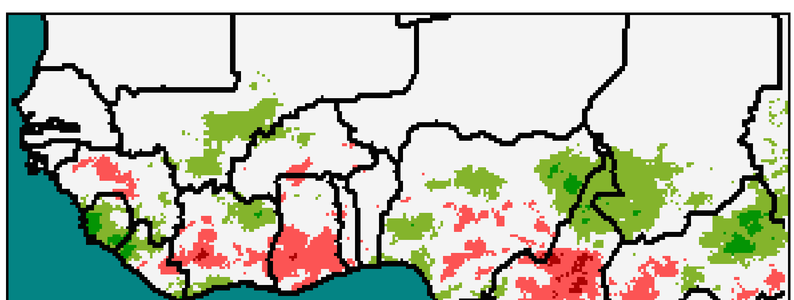

Figure 6. Difference from 1920-1980

- much below average
- slightly below average
- average
- above average
- normally dry